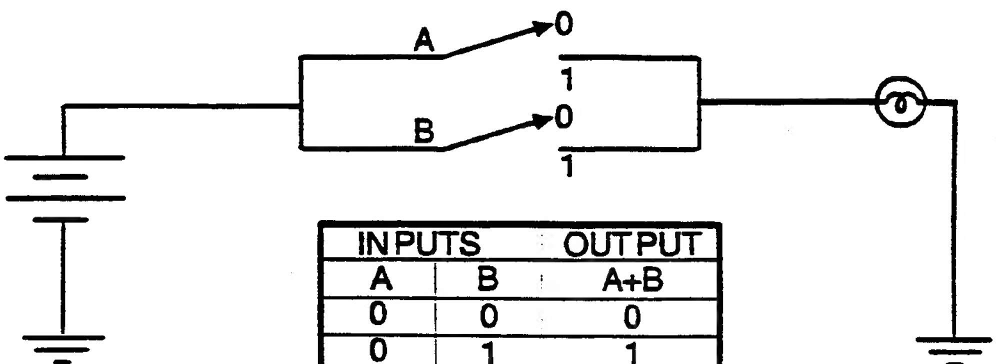
SUBCOURSE
IT0342

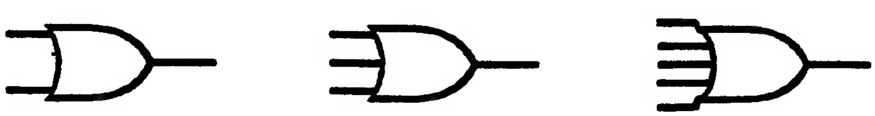
EDITION
B

US ARMY INTELLIGENCE CENTER

BASIC OPERATIONS OF BOOLEAN ALGEBRA



INPUTS		OUTPUT
A	B	A+B
0	0	0
0	1	1
1	0	1
1	1	1



THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT
ARMY CORRESPONDENCE COURSE PROGRAM

AIPD
READINESS/PROFESSIONALISM THRU GROWTH

BASIC OPERATIONS OF BOOLEAN ALGEBRA

SUBCOURSE NUMBER IT0342

EDITION B

U.S. ARMY INTELLIGENCE CENTER
FORT HUACHUCA, AZ 85613-6000

2 Credit Hours

Edition Date: August 1996

SUBCOURSE OVERVIEW

This subcourse is an introduction to Boolean Algebra, which has various usage in digital circuit design and computer application. It can be applied to simplify complex logic circuit, and it can be used in structuring database searches.

There are no prerequisites for this subcourse

This lesson replaces SA0712.

<u>TERMINAL LEARNING OBJECTIVE</u>

ACTION: You will identify the premise upon which Booles' logic is based, identify the arithmetic symbols used to represent the OR and the AND function, select the definition of the term EXPRESSION used in Boolean Algebra, identify the constants used in Boolean Algebra, identify the values for any variables used in Boolean Algebra, select the definition of a truth table, solve for the number of possible input combinations for a given logic diagram, identify the logic of AND, OR, and NOT FUNCTIONS, select the correct truth tables for AND, OR, NAND, NOR, Inhibitor, and "exclusive or" operations, select the correct expression for a NOR circuit and identify the number of inputs that may be applied to a NOT circuit.

CONDITION: Given the information contained in this subcourse.

STANDARD: To demonstrate competency of this task, you must achieve a minimum of 70% on the subcourse examination.

REFERENCE: <u>Basic Electronics</u>. NAVPERS 10087-B. 1968 Edition. Chapter 16.

<u>Mathematics</u>, Volume 3. NAVPERS 10073. 1964 Edition. Chapter 3.

<u>Traderman 1 and c.</u> NAVPERS 10378-B. 1967 edition. Chapter 11.

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LESSON

BASIC OPERATIONS OF BOOLEAN ALGEBRA

OVERVIEW

LESSON DESCRIPTION:

Upon completion of this lesson, it can be applied to simplify complex logic circuit, and it can be used in structuring database searches.

TERMINAL LEARNING OBJECTIVE:

ACTION: Identify the premise upon which Booles' logic is based; identify the arithmetic symbols used to represent the OR and the AND function; select the definition of a truth table, solve for the number of possible input combination for a given logic diagram; identify the logic of AND, OR, and NOT functions; select the correct truth tables for AND, OR, NAND, NOR, Inhibitor, and "exclusive OR" operations; select the correct expression for a NOR circuit and identify the number of inputs that may be applied to a NOT circuit. NOR circuit and identify the number of inputs that may be applied to a NOT circuit.

CONDITION: Given the information contained in this subcourse.

STANDARD: To demonstrate competency of this task, you must achieve a minimum of 70% on the subcourse examination.

	1.	Boolean algebra is not new. The symbolic operations utilized in digital computers are based on the investigations of the 19th century mathematician George Boole, and the resulting algebraic system is called Boolean algebra in his honor. Computer designers, in search of a system which would enable them to combine and manipulate binary numbers, found that Boolean algebra lent itself well to the "two valued" digital-computer elements and allowed the simplification of binary expressions quickly and efficiently. The objective of using Boolean algebra in the study of digital computes is to determine the "truth value" of a combination of two or more statements. Boole's logic is based upon the premise that a statement is either true or false. True statements have a value of 1, while false statements have a value of 0. Boole's logic is based upon the premise that a statement is either _________________or ___________________________.
true false	2.	To understand Boolean notations, a person must ignore the common usage of the arithmetic multiplication (x) and addition (+) connectives, since their use in logical operations is quite different from the arithmetic usage. In arithmetic, the symbol "x" means "multiply," and the symbol "+" means "add." In Boolean algebra, the arithmetic symbol "x" means AND, and the arithmetic symbol "+" means OR. For example, the expression A+B is read A <u>or</u> B; the expression AxB is read A <u>and</u> B. In ordinary arithmetic, digits represent arithmetic quantities; whereas, in Boolean algebra, digits represent conditions, such as ON-OFF, OPEN-CLOSED, etc.

	2. (Continued) What are the arithmetic symbols used to represent the AND and the OR function in Boolean algebra? a. AND: b. OR:
a. x b. +	3. Boole's logic is based upon the a. premise that all statements are true and false. b. theory that no two statements are true and false. c. premise that a statement is either true or false. d. theory that the digits 0 and 1 are complete truths.
c.	4. In Boolean algebra, an EXPRESSION is a group of constants and/or variables connected by one or more operations. The expression may contain parentheses, but must never contain an equality sign (=). For example, A+1 (read A <u>or</u> 1) and BC (read B <u>and</u> C) are expressions. (Note the absence of equality signs.) In Boolean algebra, as in ordinary algebra, it is not always necessary to use the multiplication connective (x). Multiplication is also indicated by the absence of a connective. For example, the expression AxB can also be expressed as AB, which has the same meaning. An EXPRESSION is a group of constants and/or ______________________________ connected by__________________or more__________________________________.

variables one operations	5. Match the arithmetic symbols in column A with their Boolean algebra functions in column B. A — B _______(1) + — a. NOT _______(2) x — b. NAND c. OR d. AND
(1) c. (2) d.	6. In ordinary algebra, there are many possible constants, including all integers (1, 2, 3, etc.) and all fractions (1/2, 1/4, etc.). For example, the decimal number 6 always means the same thing: a quantity of six, a constant, a fixed meaning. In Boolean algebra, which utilizes the binary numbering system, there are only two possible constants, 0 and 1. In Boolean algebra, the two possible constants are ________________________________ and_____________________________.
0 1	7. A group of constants and/or variables connected by one or more operations is a Boolean a. entirety. b. expression. c. equality. d. untruth.

<table>
<tr><td>b.</td><td>8. A variable is a quantity which can change by taking on the value of any constant in the numbering system. At one specific time, a variable can have the value of one constant a later time, it can take on the value of some other constant. Since there are only two possible constants in Boolean algebra, a variable can take on either of only two possible states, 0 or 1.

In Boolean algebra, the two possible values for any variable are

____________________________and___________________________.</td></tr>
<tr><td>0

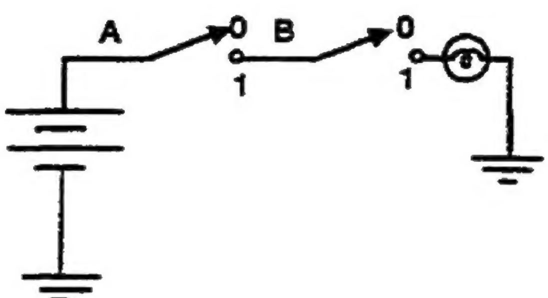
1</td><td>9. The two possible constants used in Boolean algebra are

a. 00 and 10.

b. binary and base 2.

c. true and false.

d. 0 and 1.</td></tr>
<tr><td>d.</td><td>10. A truth table is a chart of a logic function which lists all possible combinations of input values and indicates the true output value for each input combination.



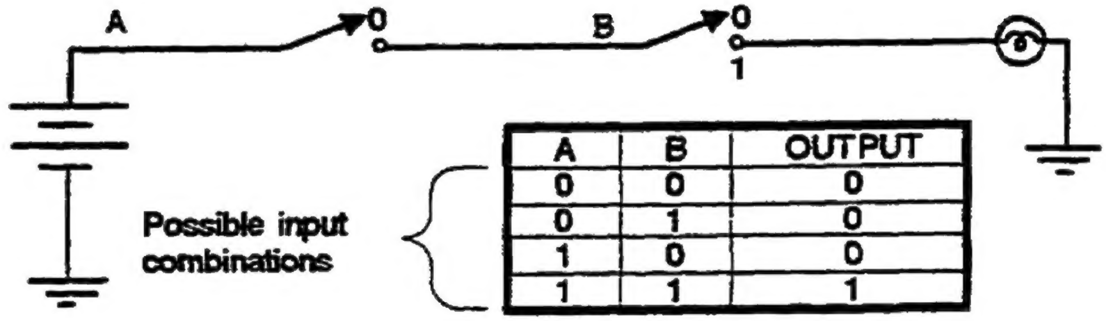
SWITCHING NETWORK

<table>
<tr><th>A</th><th>B</th><th>OUTPUT</th></tr>
<tr><td>0</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>0</td></tr>
<tr><td>1</td><td>0</td><td>0</td></tr>
<tr><td>1</td><td>1</td><td>1</td></tr>
</table>

TRUTH TABLE</td></tr>
</table>

	10. (Continued) In the preceding diagram, the truth table represents the switching network and lists all possible combinations of switches A and B. An open switch is represented by a 0; a closed switch, by a 1; therefore, their truth values are either 0 or 1. The truth table shows that both switches must be closed (1) before the lamp will light. The Boolean expression for this condition is AB (read A <u>and</u> B). A truth table is a chart of a logic function which lists all possible combinations of_________________values and indicates the___________ _______________value for each input combination.
input true output	11. In Boolean algebra, the two possible values for any variable are a. yes and no. b. 10 and 01. c. true and false. d. 0 and 1.
d.	12. It is possible to construct a truth table for a logic diagram containing any number of inputs. The simplest way to determine the number of possible input combinations is to use the number of inputs as an exponent of the number 2. For example, a truth table for a two-input logic diagram has 2^2 = 4 possible combinations of inputs; a three-input logic diagram has 2^3= 8 possible combinations of inputs, etc.

12. (Continued)



A	B	OUTPUT
0	0	0
0	1	0
1	0	0
1	1	1

In the truth table above, there are two inputs: input A and input B. There are four possible combinations of these inputs (22 = 4). The input columns are vertical and are set up like the binary numbers which equal 0, 1, 2, and 3. Notice, in the truth table above, the input combinations and the vertical columns are set (from top to bottom) like the binary numbers 00, 01, 10, and 11. A truth table for three inputs has eight possible input combinations ($2^3 = 8$), and the vertical columns are set up from 000 through 111, as shown below.

A	B	C	OUTPUT
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

How many possible combinations of inputs are there for any four-input logic diagram?

16

13. A truth table is a ______________________________ of a ______________________________ function which lists a possible combinations of input values and indicates the true __________________________ value for each __________________________ combination.

chart

logic

output

input

14. Complete the following statements.

a. A two-input logic diagram has ______________________________ possible combinations of inputs.

b. A three-input logic diagram has ______________________________ possible combinations of inputs.

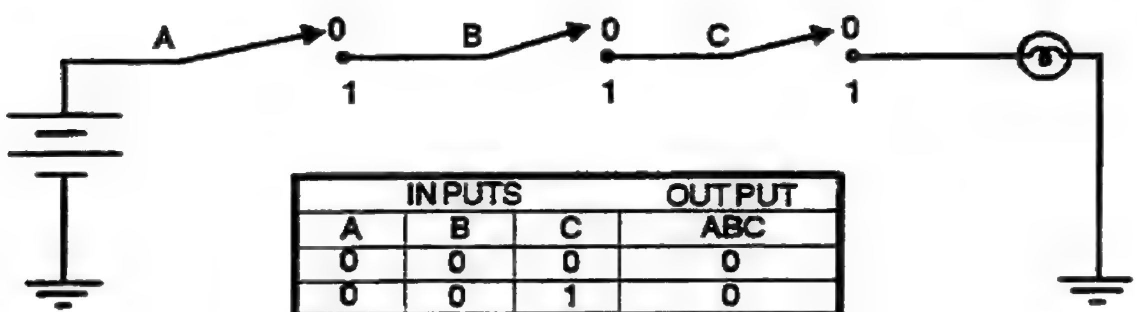
c. A four-input logic diagram has ______________________________ possible combinations of inputs.

a. four

b. eight

c. 16

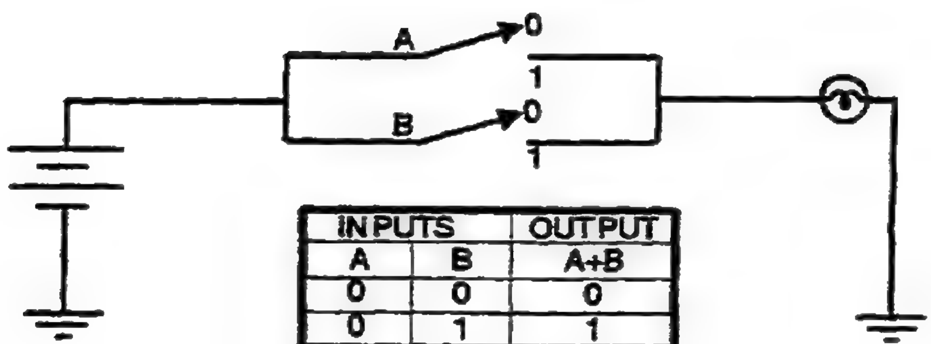
15. The AND function of Boolean algebra is stated: If, and only if, all conditions are true, the results will be true. AND logic is represented by the series switching network shown below.



INPUTS			OUTPUT
A	B	C	ABC
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

<table>
<tr>
<td></td>
<td>15. (Continued)

On page 1-7, the truth table indicates that only one combination of switch settings turns on the light; thus, if, and only if, all switches have a truth value of 1, there is an output. This is known as the AND function, because switch A <u>and</u> switch B <u>and</u> switch C must all be closed to produce an output. The Boolean expression for this condition is ABC (read A <u>and</u> B <u>and</u> C). The logic of an AND function is stated: If, and ____________________if, all conditions are________________, the result will be__________________________.</td>
</tr>
<tr>
<td>only
true
true</td>
<td>16. The OR function of Boolean algebra is stated: If any condition or all conditions are true, the result is true. The OR logic is represented by the parallel switching network shown below.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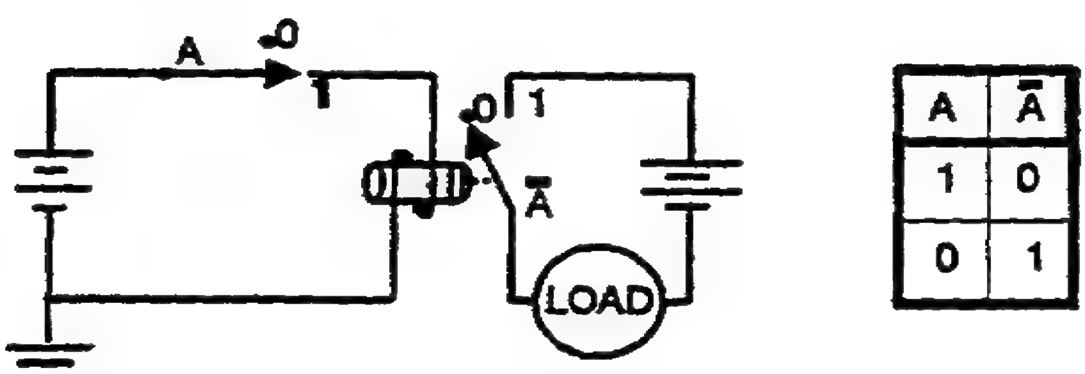
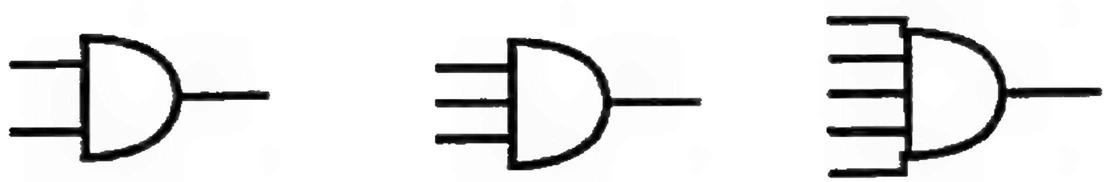
</table>

INPUTS		OUTPUT
A	B	A+B
0	0	0
0	1	1
1	0	1
1	1	1

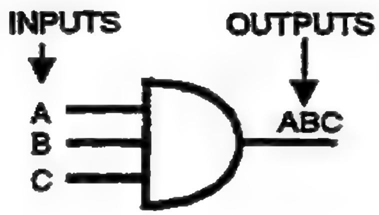
	16. (Continued) The truth table on page 1-8 indicates that either switch A or switch B or both can be closed and the lamp will light. If neither switch is closed, the lamp will not light. This is known as the OR function, because switch A switch B or both must be closed to produce an output. The Boolean expression for this condition is A+B (read A or B). The logic of an OR function is stated: If__________________condition or ______________conditions are____________________,the result is ______________.
any all true true	17. The logic of an AND function states: a. If, and only if, all conditions are false, the result will be false. b. If, and only if, all conditions are true, the result will be false. c. If, and only if, all conditions are false, the result will be true. d. If, and only if, all conditions are true, the result will be true.
d.	18. The NOT function in Boolean algebra is described as "any circuit which inverts a logic function." The symbol for the NOT function is a vinculum over the variable. For example, Ā is read as "NOT A."



	18. (Continued) In the figure on page 1-9, the truth table and the circuit for the NOT function are shown. The requirement of a NOT circuit is that the output must be the complement of the input. Thus, when switch A is closed (1), the relay opens the circuit to the load. When switch A is open (0), the relay completes the circuit to the load. The NOT function is indicated by a__________________________over the ______________________.
vinculum variable	19. The logic of an OR function states: a. If any condition or all conditions are true, the result is true. b. If any condition or all conditions are false, the result is true. c. If any condition or all conditions are true, the result is false. d. If any condition or all conditions are false, the result is false.
a.	20. In any digital-computer equipment, there are many switching networks. In order to analyze the circuit operation, it is often necessary to refer to these circuits without looking at their switching arrangements. This is done by the use of logic diagrams. Logic diagrams for the AND operation are shown below. 

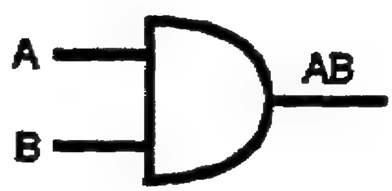
20. (Continued)

The AND-logic symbol may have two or more inputs; however, to accommodate more than three inputs, the input side of the symbol is extended, as shown by the diagram on the right. Remember, an AND circuit (AND gate) produces a true output if, and only if, all conditions are true. The logic diagram and the truth table for a three-input AND operation are shown below. Note that the output is true (1) only when all inputs are true (1).



INPUTS			OUTPUT
A	B	C	ABC
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

Construct a truth table for the two-input AND operation below.



A	B	AB
0	0	0
0	1	0
1	0	0
1	1	1

The NOT function is indicated by

21. a. the absence of 0's and 1's.

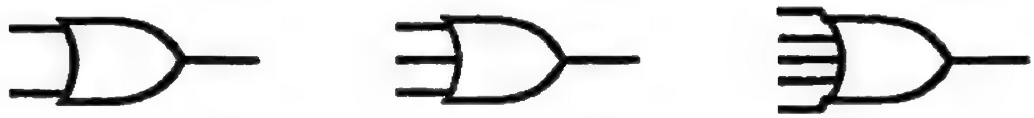
b. a vinculum over the variable.

c. the mathematical addition symbol (+).

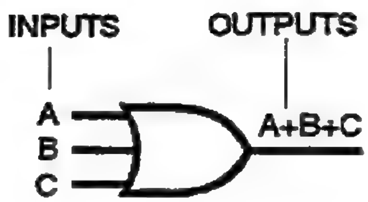
d. the mathematical multiplication symbol (x).

b.

22. Logic symbols for the OR operation are shown below.

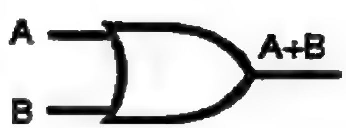


An OR-logic symbol may have two or more inputs; however, to accommodate more than three inputs, the input side of the symbol is extended, as shown by the diagram on the right. The OR operation produces a true (1) output when any input is true (1) or when all inputs are true. If all inputs are false (0), the output is false (0). The logic diagram and the truth table for a three-input OR operation am shown below.



INPUTS			OUTPUT
A	B	C	A+B+C
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

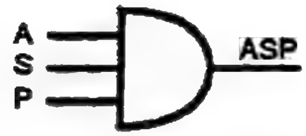
Construct a truth table for the two-input OR operation below.



INPUTS		OUTPUT
A	B	A+B

A	B	A+B
0	0	0
0	1	1
1	0	1
1	1	1

23. Complete the truth table for the three-input AND operation below.



INPUTS			OUTPUT
A	S	P	ASP
0	0	0	0
0	0	1	
0	1	0	
0	1	1	0
1			
1			
1			0
1			

A	S	P	ASP
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

24. A NOT-operation circuit, also called an INVERTER circuit, produces the complement of whatever is applied to its input. Two NOT (inverter)-logic symbols are shown below.

The maximum number of inputs to a NOT circuit is one. The output is a 1 level when the input is a 0 level; the output is a 0 level when the input is a 1 level. If the input were labeled A, the output would be labeled $\bar{A}$; if the input were labeled $\bar{A}$, the output would be labeled A. This logic symbol is called an inverter, because the output is always the complement of the input. What is the maximum number of inputs which may be applied to a NOT circuit?

one

25. Complete the truth table below which represents a three-input OR operation.

INPUTS			OUTPUT
T	R	Y	T+R+Y
0			
0			
0			1
0			
1	0	0	1
1	0	1	
1	1	0	1
1	1	1	

TRY	T-R+Y
000	0
001	1
010	1
011	1
100	1
110	1
111	1

26. The maximum number of inputs which may be applied to a NOT circuit is

a. one.

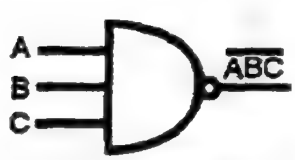
b. two.

c. three.

d. four.

a.

27. The NAND operation is a combination of the NOT and the AND operation (Not AND). The logic diagram and the truth table for a three-input NAND operation are shown below.



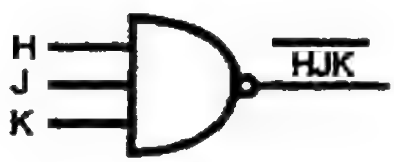
NAND-logicdiagram

INPUTS			NORMAL AND OUTPUT	NAND OUTPUT
A	B	C	A·B·C	$\overline{ABC}$
0	0	0	0	1
0	0	1	0	1
0	1	0	0	1
0	1	1	0	1
1	0	0	0	1
1	0	1	0	1
1	1	0	0	1
1	1	1	1	0

27. (Continued)

Refer to the NAND-logic diagram on the previous page. The diagram is composed of an AND gate whose output is NOTted (inverted) by the NOT circuit. The output of the AND gate is the input to the NOT circuit. The NOT circuit will invert this input and produce the complement at the output, as shown in the truth table. A NAND gate will ways NOT (invert) an ANDed expression. Note that the whole quantity of ABC is complemented, not just the separate variables.

Complete the truth table below for the three-input NAND operation.



INPUTS			NAND OUTPUT
H	J	K	$\overline{HJK}$
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	
1			
1			
1			
1			0

HJK	$\overline{HJK}$
000	1
001	1
010	1
011	1
100	1
101	1
110	1
111	0

28. The NOR operation is a combination of the NOT and the OR operation (Not-OR). The logic diagram and the truth table for a three-input NOR operation are shown below.

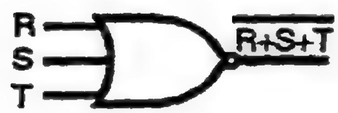
NOR-logic diagram

INPUTS			OR OUTPUT	NOR OUTPUT
A	B	C	A+B+C	$\overline{A+B+C}$
0	0	0	0	1
0	0	1	1	0
0	1	0	1	0
0	1	1	1	0
1	0	0	1	0
1	0	1	1	0
1	1	0	1	0
1	1	1	1	0

The NOR-logic diagram above is composed of an OR gate whose output is NOTted (inverted) by the NOT circuit. The output of the OR gate is the input to the NOT circuit; the NOT circuit inverts this input and produces the complement at the output, as shown in the truth table. A NOR gate will always NOT (invert) an ORed expression. Note that the whole

28. (Continued)

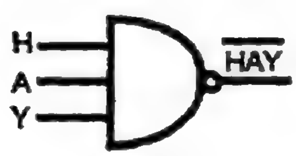
quantity A+B+C is complemented, not just the separate variables. Complete the truth table below for the three-input NOR operation.



INPUTS			NOR OUTPUT
R	S	T	$\overline{R+S+T}$
0	0	0	
0	0	1	0
0	1	0	0
0	1	1	
1			0
1			
1			0
1	1		

RST	$\overline{R+S+T}$
000	1
001	0
010	0
011	0
100	0
101	0
110	0
111	0

29. Complete the truth table below for the NAND operation.

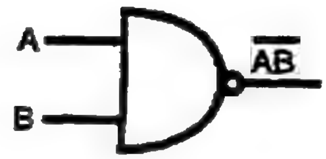


INPUTS			NOR OUTPUT
H	A	Y	$\overline{HAY}$
0	0	0	
0	0		
0	1		1
0		1	
1		0	1
1	0		
1	1		1
		1	

HAY	$\overline{HAY}$
000	1
001	1
010	1
011	1
100	1
101	1
110	1
111	0

30. The output from a NAND gate and the output from a NOR gate will always be a NOTted expression indicated by a vinculum extending over the entire output expression.

30. (Continued)



Refer to the NAND and NOR gates above. Inputs A and B are expressed at the output as $\overline{AB}$. Inputs C and D of the NOR gate above are expressed as $\overline{C+D}$ at the output. Note that the whole quantity is complemented at the output of both gates, not just the separate variables.

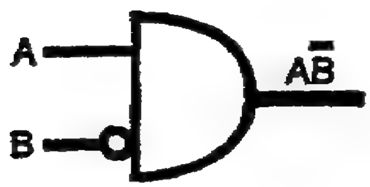
Write the output expression for the following NOR gate.

$\overline{X+Y+Z}$

31. Complete the truth table below for the NOR operation.

INPUTS			OUTPUT
D	E	G	$\overline{D+E+G}$
0		0	
0	0		0
	1		
		1	0
1		0	
	0		0
1			
		1	

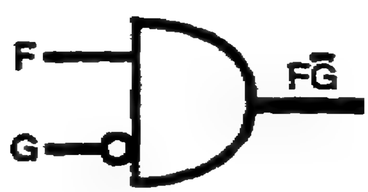
32. An INHIBITOR circuit is a combination of an AND gate and a NOT circuit in which the NOT circuit is inserted between one input terminal and the AND gate. An INHIBITOR circuit performs the same logic as the basic AND gate with the exception that one input is inverted at the inhibitor circuit.



INPUTS		OUTPUT
A	B	$A\bar{B}$
0	0	0
0	1	0
1	0	1
1	1	0

Refer to the logic diagram and truth table above. Input B is the inhibited input. A 1 output is obtained only when a 1 is applied to input A and 0 is applied to input B. The same logic would be obtained if input A were the inhibited input, only reversed.

Complete the truth below for the two-input INHIBITOR operation.



INPUTS		OUTPUT
F	G	$F\bar{G}$
0	0	
0	1	
1	0	
1	1	

33.

The output for the NOR gate above is

a. $\overline{B\ A\ G}$.

b. $\overline{B}+\overline{A}+\overline{G}$.

c. $\overline{BAG}$.

d. $\overline{B+A+G}$.

d.

34. An EXCLUSIVE-OR circuit has two input terminals. No output is produced when both of the inputs are false (0) or when both of the inputs are true (1). However, when the inputs differ from each other (i.e., one input false (0) and the other input true (1)), an output is produced. As shown below, the output of an EXCLUSIVE-OR circuit is true (1) when one, but <u>not</u> both, of the inputs is true.

EXCLUSIVE-OR symbol

INPUTS		OUTPUT
A	B	
0	0	0
0	1	1
1	0	1
1	.1	0

The logic of an EXCLUSIVE-OR circuit is stated: An output is

_____________when________________, but not_____________,

of the______________is true.

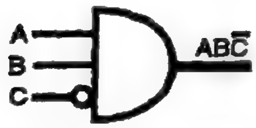
true

one

both

inputs

35. Compete the truth table below for the three-input INHIBITOR operation.



INPUTS			OUTPUT
A	B	C	$AB\bar{C}$
0	0	0	0
0	0		
0		0	
0	1		0
	0	0	
	0	1	
1		0	
	1	1	0

ABC	$AB\bar{C}$
000	0
001	0
010	0
011	0
100	0
101	0
110	1
111	0

36. The logic of an EXCLUSIVE-OR gate is stated:

a. An output is true when one input or both inputs are true.

b. An output is true when one, but not both, of the inputs is true.

c. An output is true when one input or both inputs are false.

d. An output is true when one, but not both, of the inputs is true or false.

b.

You have completed the program and you should be ready for the Practice Exercise. You should understand the objectives as stated on page i & iv, and all the material presented in the lesson. If you don't understand an area, go to the applicable area and review the material until you are sure of complete understanding..

LESSON

PRACTICE EXERCISE

1. What is the premise upon which Boole's logic is based?

2. What arithmetic symbols are used to represent the AND and the OR function?

   a. AND:

   b. OR:

3. Select the definition of the term EXPRESSION used in Boolean algebra.

   a. A group of constants and/or variables connected by one or more operations.

   b. A group of connectives and/or operations connected by a constant.

   c. A group of operations and/or variables connected by a constant.

   d. A group of constants and/or variables connected by an equality sign.

4. What are the constants used in Boolean algebra?

5. What are the values for any variable used in Boolean algebra?

6. Select the definition of truth table.

   a. A chart of a logic function which lists all combinations of input values for only one output.

   b. A chart of a logic function which lists all possible combinations of input values and indicates the true output value for each input combination.

   c. A chart of a logic function which lists only input combinations for a true output.

   d. A chart of a logic function which lists all possible combinations of input values and indicates only one output.

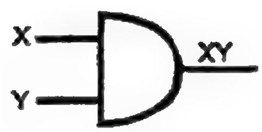
7. What is the number of possible input combinations for a four-input logic diagram?

8. State the logic of an AND function.

9. State the logic of an OR function.

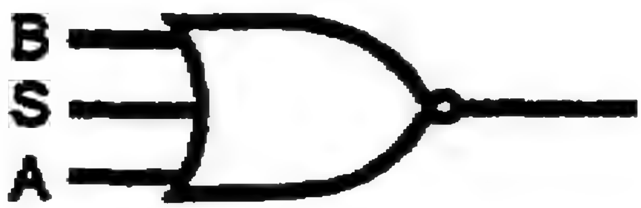
10. How is the NOT function indicated?

11. Construct a truth table for the AND operation below.

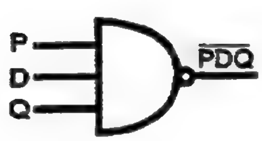


INPUTS		OUTPUT
X	Y	XY

12. Write the output expression for the NOR gate below.



13. Construct a truth table for the NAND operation below.



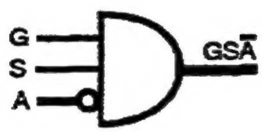
INPUTS			NOR OUTPUT
P	D	Q	$\overline{PDQ}$

14. What is the maximum number of inputs that may be applied to a NOT circuit?

15. Construct a truth table for the NOR operation below.

INPUTS			NOR OUTPUT
F	G	H	$\overline{F+G+H}$

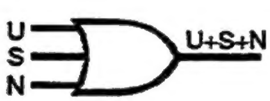
16. Construct a truth table for the INHIBITOR operation below.



INPUTS			NOR OUTPUT
G	S	A	$GS\overline{A}$

17. State the logic of an EXCLUSIVE-OR circuit.

18. Construct a truth table for the OR operation below.



INPUTS			NOR OUTPUT
U	S	N	U+S+N

LESSON

PRACTICE EXERCISE

ANSWER KEY AND FEEDBACK

Correct Answer and Feedback

1. A statement is either true or false.

2. a. x

   b. +

3. a.

4. 0 and 1

5. 0 and 1

6. b.

7. 16.

8. If, and only if, all conditions are true, the result will be true.

9. If any condition or all conditions are true, the result is true.

10. By a vinculum over the variable.

11.

X	Y	XY
0	0	0
0	1	0
1	0	0
1	1	1

12. $\overline{B+S+A}$

13.

PDQ	$\overline{PDQ}$
000	1
001	1
010	1
011	1
100	1
101	1
110	1
111	0

14. one.

15.

FGH	$\overline{F+G+H}$
000	1
001	0
010	0
011	0
100	0
101	0
110	0
111	0

16.

GSA	$GS\overline{A}$
000	0
001	0
010	0
011	0
100	0
101	0
110	1
111	0

17. An output is true when one, but not both, of the inputs is true.

18.

USN	U+S+N
000	0
001	1
010	1
011	1
100	1
101	1
110	1
111	1

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